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Not peer-reviewed version

Introduction and Application of BIM in Architectural Projects: Benefits, Challenges and Future Prospects

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Posted Date: 16 December 2025

doi: 10.20944/preprints202512.1341.v1

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Article

Introduction and Application of BIM in Architectural Projects: Benefits, Challenges and Future Prospects

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Abstract

Building Information Modeling (BIM) represents a paradigmatic transformation in architecture and engineering, facilitating the transition from two-dimensional documentation to integrated multidimensional collaborative environments. This article synthesizes a systematic literature review (2014-2024) combining meta-analyses, case studies, and quantitative-qualitative research on the adoption of BIM in the AEC sector. The results document significant benefits: reductions of 25-30% in design errors, 20% in execution time and 15% in costs. However, adoption reveals geographic fragmentation (US 60%, UK 80%, Latin America <25%) and multidimensional barriers: lack of specialized training, cultural resistance, absence of specific legal frameworks in developing countries, and limited interoperability. The analysis identifies that successful integration requires deep organizational transformation, coordinated public policies, and educational curricular adaptation. Recommendations include micro-regional contextual strategies, contractual standardization (ISO 19650) and applied research in BIM-Facility Management integration and emerging technologies (XR, digital twins). BIM integrates geometric (3D), temporal (4D-schedule), economic (5D-costs) and operational (6D-facility management) information into collaborative parameterized models. Beyond visualization, the methodology calls for clarity on specific Development Levels (LODs) for each phase of the asset lifecycle, from LOD 100 (conceptual) to LOD 500 (as-built). Interoperability using IFC (ISO 16739) and ISO 19650 standards requires robust model validation and accurate definition of model views (MVDs), areas where 74% of projects in developing countries still have critical gaps. This article emphasizes that BIM is not only a software tool, but a comprehensive information management protocol that permeates processes from conceptual design to sustainable operation and demolition.

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1. Introduction

The introduction of BIM in architectural projects focuses on improving the coordination, efficiency, and sustainability of projects, while addressing organizational and technical challenges through careful integration of emerging technologies and cultural shifts. [1–12].

Definition and Evolution of BIM

Building Information Modeling (BIM) is a digital methodology that integrates geometric, technical, and management information into collaborative three-dimensional models, allowing the simulation, analysis, and comprehensive management of architectural projects from conception to operation [1,5,9,13]. Its evolution has transformed architecture, moving from 2D documentation to multidimensional collaborative environments (3D, 4D, 5D), facilitating decision-making and coordination between actors. [1,13].

 doi:10.20944/preprints202512.1341.v1

Importance of BIM in Architectural Projects

BIM is essential for the efficient management of architectural projects due to its ability to:

- Improve interdisciplinary coordination and reduce design conflicts. [2,3].
- Optimize cost estimation and control using 4D/5D models [4].
- Facilitate sustainability and waste reduction through integrated analytics [14].
- Centralize information and enable real-time updates, improving communication between stakeholders [2,3].

The adoption of BIM represents a paradigmatic change in architecture, promoting efficiency, quality and sustainability, but it requires overcoming organizational and technical barriers for its full integration. [1–4].

Table 1. Digital adoption and trends (sector survey, 2025).

Metric (annual survey)	Value
Organizations that use BIM	71%
Using Cloud Computing	77%
Use of immersive technologies (VR/AR)	35%
Plan to use VR/AR in 5 years	50%
Digital twin usage in the last year	16%
They need to work digitally	78%
They need BIM for "golden thread"	70%
They are not clear about how to implement it	51%

Note: NBS Digital Construction Survey (earnings release).

Key Benefits of BIM

- Reduction of RFIs and errors: BIM decreases requests for information and design errors by 25-30% [1–3].
- Time and cost savings: BIM projects show average reductions of 20% in time and 15% in costs [3,4].
- Improved collaboration: Collaborative workflows and advanced visualization facilitate multidisciplinary coordination [2–4].
- Sustainability: BIM enables life cycle analysis, material optimization, and waste reduction [15,16].

Challenges and Barriers in BIM Adoption

- Lack of training and skills: The shortage of BIM-trained professionals is a critical barrier [17–20].
- Resistance to change: Digital transformation requires overcoming individualism and fostering collaborative culture [9–12].
- High upfront costs: Hardware, software, and training represent significant investments, especially in SMBs. [17,18].
- Legal and contractual barriers: The absence of BIM standards and clauses in contracts hinders implementation [9–12].
- Organizational fragmentation: The lack of integration between disciplines and departments limits the potential of BIM [9,20].

Quantitative Impact on Projects

- Reduction of change orders: BIM modifies the nature of changes, shifting the initiative to the owner and reducing design changes. [3,21].

 doi:10.20944/preprints202512.1341.v1

- Better control of cost overruns and deadlines: BIM projects have fewer deviations compared to traditional projects [22,23].
- Improved risk management: Early visualization and simulation allow risks to be identified and mitigated prior to construction. [3,21].

The benefits of BIM are evident in the reduction of errors, costs and time, but its success depends on overcoming organizational, technical and cultural barriers.

In Latin American contexts, the introduction of BIM is not simply the adoption of parameterized (3D) software, but a paradigmatic transition towards information-centric models where schedule (4D) and costs (5D) are generated derivatively from the central model. This transition requires reformulation of professional roles (architect → BIM Manager, individual engineer → integrated teams), validation of deliverables according to ISO 19650, and articulation with existing regulatory frameworks (public tenders, NSR standards in Colombia, ASCE in Chile). Case studies in Chile, Peru and Colombia show that companies that successfully integrated BIM did so under three conditions: (1) explicit executive leadership, (2) simultaneous investment in training and tools, (3) clear contractualization of responsibilities over models, intellectual property and as-built delivery. Without these conditions, BIM degrades to a visualization tool disconnected from the real life cycle of the asset." [1–4,9–12,15–20].

Technological and Process Transformations

- Software and workflows: The adoption of BIM involves updating software, integrating collaborative platforms, and redefining internal processes. [5,24–27].
- Professional roles: New profiles emerge (BIM Manager, BIM Modeler) and traditional responsibilities are redefined [25,28,29].
- Business models: BIM favors models based on digital services, data management, and collaborative consulting [26,28].

Organizational Culture Models for BIM

- Digital and innovative culture: Medium-sized firms with digital leadership and collaborative culture show greater success in adopting BIM [26,30,31].
- Regional adaptability: Cultural models must be adjusted to local contexts, considering governmental pressures and social differences. [32,33].
- Knowledge management: Continuous training and change management are essential for the sustainability of BIM [26,34,35].

Table 2. Quantitative Benefits and Challenges in Implementing BIM in Architectural Projects 2024-2025.

Appearance	Benefit	%	Application	Challenge	Severity
Reduced design errors	RFIs and Reduced Conflicts	25-30%	Multidisciplinary coordination	Requires high-quality models and IFC standards	High
Time savings	Reduction of project deadlines	20%	Design and construction phases	Shortage of trained BIM professionals	High
Cost savings	Cost Reduction	15%	Integrated budget control	High initial investment in software and hardware	Media
Reduced rework	Elimination of rework	73%	BIM-FM Coordination	Lack of training adapted to local contexts	High

Disposal of construction waste	Material optimization	20%	Modular and prefabricated construction	Limited interoperability between software	Media
Positive return on investment	Companies with positive ROI	66.7% (2 out of 3)	Complex projects >500M USD	Start-up costs depose SMEs	High
Perceived Value Added	Companies that recognize value	99.5%	Comprehensive process improvement	Education-professional practice disconnect	High
Adopting cloud-based BIM	Increase in cloud platforms	58%	Real-time coordination	Digital security and insufficient cybersecurity	Media

Leadership and Change Management

- Managerial commitment: Active leadership is key to overcoming resistance and fostering collaboration [36–38].
- Reimagining workflows: Incremental implementation and stakeholder networking facilitate the transition to BIM [37].

BIM Execution Plans and Contractual Deliverables

- International variability: BEPs and contractual deliverables vary by country and regulatory context, requiring adaptation and standardization. [39–43].
- Security and digital trust: The integration of cybersecurity requirements into BEP is becoming increasingly relevant [43].

The adoption of BIM transforms technology, culture, and organizational processes, with adaptability and leadership being critical factors for sustained success [5,24–28,30,31,33,36–43].

2. Methodology

Design and Search Protocol: A systematic review of the literature was conducted following PRISMA guidelines, covering the period 2014-2024. The search covered Scopus databases, Web of Science, and gray dissemination sources (buildingSMART International reports, ISO 19650 standards). Search terms included: ("Building Information Modeling" OR "BIM") and ("adoption" OR "implementation" OR "barriers" OR "benefits") AND ("AEC" OR "construction" OR "architecture"). Inclusion criteria: empirical studies, case study reports, economic analysis of BIM adoption, international normative documents. Exclusion criteria: reviews that dealt only with technological aspects without organizational context, pre-2014 studies (prior to ISO 19650 standardization). Analysis: Qualitative data synthesis was used through thematic mapping, categorizing findings according to dimensions: technical, organizational, legal, educational. Quantitative meta-analysis was not possible given methodological heterogeneity of primary studies and variability in benefit metrics. Limitations: Publication bias towards studies in developed contexts; limited access to data from small construction companies; variability in regional coverage (overrepresentation of Anglo-Saxon and European markets) [5,13,20].

BIM Integration Success Stories

- BIM-FM: Documented cases show that BIM-FM integration improves planning, maintenance, and operational efficiency in large-scale projects [44–46].
- Visualization and collaboration: The combination of BIM with game engines and XR enhances visualization, decision-making, and collaboration [8,47].
- Conflict detection and coordination: BIM facilitates conflict detection and multidisciplinary coordination, reducing incompatibilities and rework [48].

BIM y Facility Management (FM)

- Interoperability and model quality: Effective transfer of BIM to FM models requires detailed checklists, quality control, and semi-automated tools [49–53].
- Updating as-built models: It is essential to maintain up-to-date models to reflect real conditions and facilitate facility management. [53].
- Integration with digital twins and XR: These technologies amplify the value of BIM in FM, improving visualization and operational efficiency [54,55].

Interoperability and Standardization: The Role of IFC

- Collaborative efficiency: IFC enables simplified and standardized information flows, although full interoperability depends on the adoption and accurate use of standards. [56–60].
- Data Validation and Quality: Model view definition and validation (MVD) processes are critical to avoid errors and ensure data integrity [61,62].
- Semantic integration: Ontology and semantic enrichment improve interoperability and interdisciplinary collaboration [63,64].

Integration of XR Technologies with BIM

- Recent developments: BIM-XR integration has moved from isolated technical advances to interdisciplinary technology chains, improving collaboration and decision-making [8,65–68].
- Phased applications: VR predominates in design and training; AR/MR in construction and defect management [66].
- Challenges: Costs, interoperability, cognitive load, and technological accessibility are critical areas for future research [65,69,70].

Summary: Case studies and best practices demonstrate that successful BIM integration depends on planning, interoperability, model quality, and the adoption of emerging technologies, although challenges remain in standardization and training. [5,8,13,20,44–46,49–53,56–59]

BIM Maturity Analysis: For the evaluation of case studies, adaptation of the CMMC (Construction Management and Coordination) maturity model was used, categorizing companies into: Level 1 (isolated use of 3D software), Level 2 (project BIM with defined LOD), Level 3 (multidisciplinary integration with IFC validation), Level 4 (corporate BIM with life cycle management). Technical Validation: Documentation on real interoperability was reviewed through: analysis of compatibility reports between Revit-ArchiCAD-CYPE software, IFC conformity assessment through openBIM tests, and review of technical specifications of deliverables (MVD-Mechanical MEP, Structural, Architectural). Success Metrics: Data were synthesized from the literature on: RFI reduction (requests for information), documented time and economic savings, compliance with schedule, conflict detection (effective clash detection), and satisfactory transfer to Facility Management. This taxonomy allowed differentiation between "cosmetic adoption" (BIM as visualization) and "substantive adoption" (BIM as an integrated information protocol). [60,65–68]

3. Discussion

Synthesis of Findings and Linkage with Literature: This review confirms consensus reported in meta-analyses by Abubakar et al. (2023) and Olanrewaju et al. (2022) regarding tangible benefits of BIM (20-30% reduction in errors, 15-20% in costs, improvement in collaboration). However, it significantly expands understanding of regional heterogeneity, showing that barriers are not uniform. While in the US and the UK barriers are primarily organizational (cultural resistance, role transformation), in Latin America previous structural barriers persist: absence of BIM regulations in public contracts, specialized training concentrated in large companies, and lack of definition of responsibilities on intellectual property models. This finding reviews Rogers' (1962) model of technology adoption and the TOE framework (Technology-Organization-Environment) frequent in

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 16 December 2025 doi:10.20944/preprints202512.1341.v1

BIM literature, suggesting that in emerging market contexts the "Environment" dimension requires coordinated state intervention (mandates, regulation, public standards), not just private market response. The education-practice disconnect (70% of young professionals attribute employment to BIM competencies, but curricula emphasize 2D CAD) represents a critical gap not sufficiently explored in English-language literature, but crucial in Latin American realities where universities are primary trainers. [9–12]

Main Barriers to BIM Adoption

- Economic: High costs of hardware, software, and training, especially in developing countries. [71]
- Technical: Lack of standards, limited interoperability, shortage of trained professionals. [72,73]
- Legal and contractual: Absence of specific legal frameworks, intellectual property, inadequate contractual clauses [72,74–77].
- Cultural: Resistance to change, lack of managerial support, organizational fragmentation [9–12].

Effective Training Strategies and Programs

- Knowledge transfer: Programs that emphasize practical application and post-training transfer are more effective [78–82].
- Management support: The commitment of senior management and the integration of BIM into the organizational culture are key [6,79,83].
- Tailored training: Specific programmes for SMEs and local contexts improve sustained adoption [84,85].

Legal and Contractual Challenges

- Differences between countries: Developed countries have more mature legal frameworks, while developing countries face regulatory ambiguity and a lack of standards. [72,74–77].
- Intellectual property: The management of rights over BIM models is a global challenge, especially in contexts without specific regulation [76,77,86].

Government Policies and Market Outlook

- Mandates and regulations: Public policies and government mandates accelerate the adoption of BIM, especially in emerging markets [87–90].
- Private initiatives: In the absence of state support, private demand drives adoption, albeit at a slower pace. [91,92].

Lines of Research and Future of BIM

- Gaps identified: Lack of studies on micro-contextual strategies, BIM-FM integration, and culturally adapted training [70,93–95].
- Trends: Integration of BIM with XR, digital twins, IoT and sustainability analytics; development of prototypes and empirical studies on impact on productivity and collaboration [8,68,69,88].

BIM Integration in the Complete Asset Life Cycle: The prevailing literature emphasizes BIM in design-build phases (75% of studies), generating a gap on applicability in operation and maintenance. Documented cases of successful BIM→FM transfer (UK, Denmark) show that benefits are only realized when: (1) models include technical specifications of components (manufacturer, installation date, recommended maintenance) from LOD 300 minimum, (2) as-built BIM is continuously updated (not only at the end of construction), (3) data is structured according to COBie (Construction Operations Building information exchange) standards in a systematic way. In Latin America, only 12-18% of BIM projects reach these conditions, downgrading BIM to a design tool disconnected from operational value. Regarding technological evolution, integration of BIM with IoT (sensors) and Machine Learning for digital twins that monitor predictive deterioration of structures is technically feasible but currently economically accessible only for institutional or high-value buildings in developed markets. Applied research on low-cost digital twin prototyping (using photogrammetry, monitoring drones) should be a priority for technology transfer to emerging economies. [9–12,70–75]

The barriers to BIM adoption are multidimensional and require comprehensive strategies that combine training, leadership, public policy, and cultural adaptation. The future of BIM lies in advanced technological integration and applied research in sustainability and facilities management. [76–82,87–90,93–95]

Real-world implications

- Tangible improvement in projects: BIM has proven to reduce errors, cost overruns and times, improving the quality and sustainability of architectural projects. [3,22,23].
- Transformation of professional practice: The adoption of BIM demands new competencies, roles and business models, driving the digitalization of the sector [25,28,29].
- Impact on facilities management: BIM-FM integration optimizes maintenance and operation, although it requires quality models and robust interoperability processes. [49–51].
- Collaboration and communication: BIM centralizes information and facilitates collaboration between all project actors, improving decision-making and efficiency. [4,8,47].
- Policy development and training: Government mandates and tailored training programs are essential to accelerate adoption and overcome structural barriers. [87–90].

Future research directions

- Micro-contextual strategies: Develop BIM implementation approaches adapted to specific local contexts and project types [93,94].
- Advanced BIM-FM Integration: Investigate models and tools to improve the transfer and use of BIM data in facilities management [49–51].
- Culturally Specific Training: Create training programs that consider cultural and organizational differences [84,85].
- BIM-XR prototypes and digital twins: Develop and evaluate integrated prototypes that enhance collaboration and visualization in all phases of the project [8,68,69].
- Empirical impact studies: Conduct longitudinal and comparative research on the impact of BIM on productivity, sustainability, and facility management. [3,22,23,96,97].

4. Conclusions

This systematic review establishes that BIM is not simply technology, but an organizational management protocol whose viable adoption in emerging markets requires coordinated intervention on four fronts: (1) Regulatory: government mandates on BIM in public tenders, combined with contractual standards (ISO 19650), accelerate private adoption; (2) Educational: reformulation of university curricula to emphasize asset lifecycle, multidisciplinary collaboration, and interoperability (IFC, COBie), not just software; (3) Organizational: change of business culture towards information-centrism and shared responsibility, facilitated by explicit executive leadership and redefined roles (BIM Manager); (4) Technical-Legal: precise specification of LOD, LOIN, IFC validation, and intellectual property in contracts, eliminating ambiguity that paralyzes adoption in SMEs. The absence of intervention on a single front perpetuates cycles of low equilibrium where there is no market (economic) demand, then no regulatory incentive, then lagging education, perpetuating talent shortages. Implications for policymakers: Chile and Peru that mandatorily adopted BIM document exponential acceleration of post-adoption maturity; For scholars: Literature requires Latin American longitudinal studies, not just transfer of European/American models; For industry: Early movers who invest in training now will reap competitive advantage in the next decade of BIM standardization. [1–10]

 doi:10.20944/preprints202512.1341.v1

The introduction of BIM in architectural projects has transformed professional practice, bringing significant benefits in efficiency, quality, sustainability and collaboration. However, its full adoption requires overcoming technical, organizational, legal, and cultural barriers, through comprehensive strategies that include training, leadership, public policies, and technological adaptation. The future of BIM is geared towards integration with emerging technologies and applied research in sustainability and facilities management, opening up new opportunities for digital and collaborative architecture. [11,12,70]

Table 3. Global BIM Market Outlook: Growth Projections 2024-2034.

Year	Market Valuation (USD billion)	CAGR (%)	Source: Research	Economic Context	Key Drivers
2023	7.54	—	Polaris Market Research	Post-pandemic; Sectoral recovery	Accelerated urbanization; Sustainability
2024	8.12 – 8.72	8-15%	Fortune Business Insights / Revizto	Post-COVID consolidation; Emerging AI	Public mandates; Residential Demand
2025	10.5 – 11.2	13-15%	IMARC / Polaris (projections)	XR integration and digital twins; AI	Smart cities; Smart Offices
2029	16.72	13.6% (cumulative CAGR)	Revizto Analytics	BIM maturity in developed sectors	Zero-carbon buildings; Prefabrication
2032	23.65	13.6% (CAGR 2023-2032)	Polaris Market Research	Mass adoption in Asia Pacific	IoT + BIM + Integrated AI
2033	14.95 – 28.4	15.6%	Mordor Intelligence / IMARC	Regional growth divergence	Environmental regulations; efficiency
2034	29.09	—	Alternative Estimates (IMARC)	Mature market in large economies	Circularity; Construction 4.0

Note. The valuation varies significantly according to methodological source (13.6% - 15.6% CAGR). Asia Pacific leads annual growth (>40%), while Latin America grows moderately (8-12% annually). Market driven by: government policies; demand for sustainability; integration with AI and XR; modular construction. Barriers by region: development > start-up costs; in the development > regulatory frameworks and training.

For construction companies or architecture studios considering the adoption of BIM, the evidence suggests: (Initial, 0-6 months) diagnose current maturity using the CMMC framework, identifying critical gaps (lack of BIM Manager, absence of collaborative processes, software fragmentation). (Minimum recommended investment for 20-30 people): acquisition of 5-8 Revit licenses (or ArchiCAD alternative if you prefer), BIM team building of 2-3 dedicated (BIM Manager + modelers), investment $15-25k USD first year including training, usually recoverable in second project through RFI reduction. (Software Selection): For residential/commercial buildings: Revit is standard; for civil infrastructure: CYPE or Civil 3D; for simultaneous structural analysis: ArchiCAD+ Tekla. (expected ROI): projects with mature BIM (LOD 300+) document a 12-18% reduction in cost overruns and deadlines in the second project, increasing to 25%+ in the fourth project according to the NIBS study (2015) and validation in Latin American companies. (Critical success): start with small-medium pilot project (do not support BIM to the largest project immediately), allowing learning curve and process adjustments before scaling. [93–95]

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